MINING METHODS AND COSTS AT THE PIOKEE MINING UNIT AND THE PIOKEE EXPERIMENTAL MINING PROJECT, THE EAGLE-PICHER CO. (TRI-STATE MINES), OTTAWA COUNTY, OKLA.

BY J. B. ELIZONDO

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MINING METHODS AND COSTS AT THE PIOKEE MINING UNIT AND THE PIOKEE EXPERIMENTAL MINING PROJECT, THE EAGLE-PICHER CO. (TRI-STATE MINES), OTTAWA COUNTY, OKLA.[1]

by

J. B. Elizondo[2,3]

INTRODUCTION AND SUMMARY

This paper, which describes mining methods and practices at the Piokee mining unit and the Piokee experimental mining project of The Eagle-Picher Co. in northeast Oklahoma, is one of a series being prepared by the Federal Bureau of Mines on mining methods, practices, and costs in various mining districts of the United States.

The Piokee unit, comprising the Piokee, Howe, Lucky Syndicate, and parts of the Netta White and Otis White leases, is in the SW1/4, W1/2NW1/4SE1/4, and W1/2SW1/4SE1/4 sec. 17, T. 29 N., R. 23 E., Ottawa County, Okla. (figs. 1 and 2). The 200-acre tract is adjacent to the town of Picher and near the heart of the Picher field of the Tri-State zinc-lead mining district.

The Piokee was 1 of 15 mining units operated by The Eagle-Picher Co. in the Picher field before mining was suspended July 31, 1957, because of declining zinc and lead prices. Operations were resumed in 10 units, but the Piokee remained idle because its known reserves were too low in zinc and lead content for economic mining at existing metal prices.

Mining methods and practices at the Piokee unit differed little from those at other mechanized mines in the Picher field until the spring of 1957. Although relatively high unit output and low unit costs were achieved despite scattered working faces and long haulage distances, the officials of The Eagle-Picher Co. realized that the future of mining in the Picher field depended largely on the ability of operators to mine profitably the low-grade ores, which comprise the predominant part of the field's remaining ore reserve.

In early 1957 the company decided to conduct an experiment to determine what could be done to increase mining efficiencies under carefully controlled conditions, using the most suitable equipment and facilities at hand. A

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[1] Work on manuscript completed April 1959.

[2] General superintendent of mines, Tri-State Mines, The Eagle-Picher Co., Cardin, Okla.

[3] In preparing this report the author was assisted by Burton M. Reynolds, mining engineer, Bureau of Mines, Region IV, Rolla, Mo.

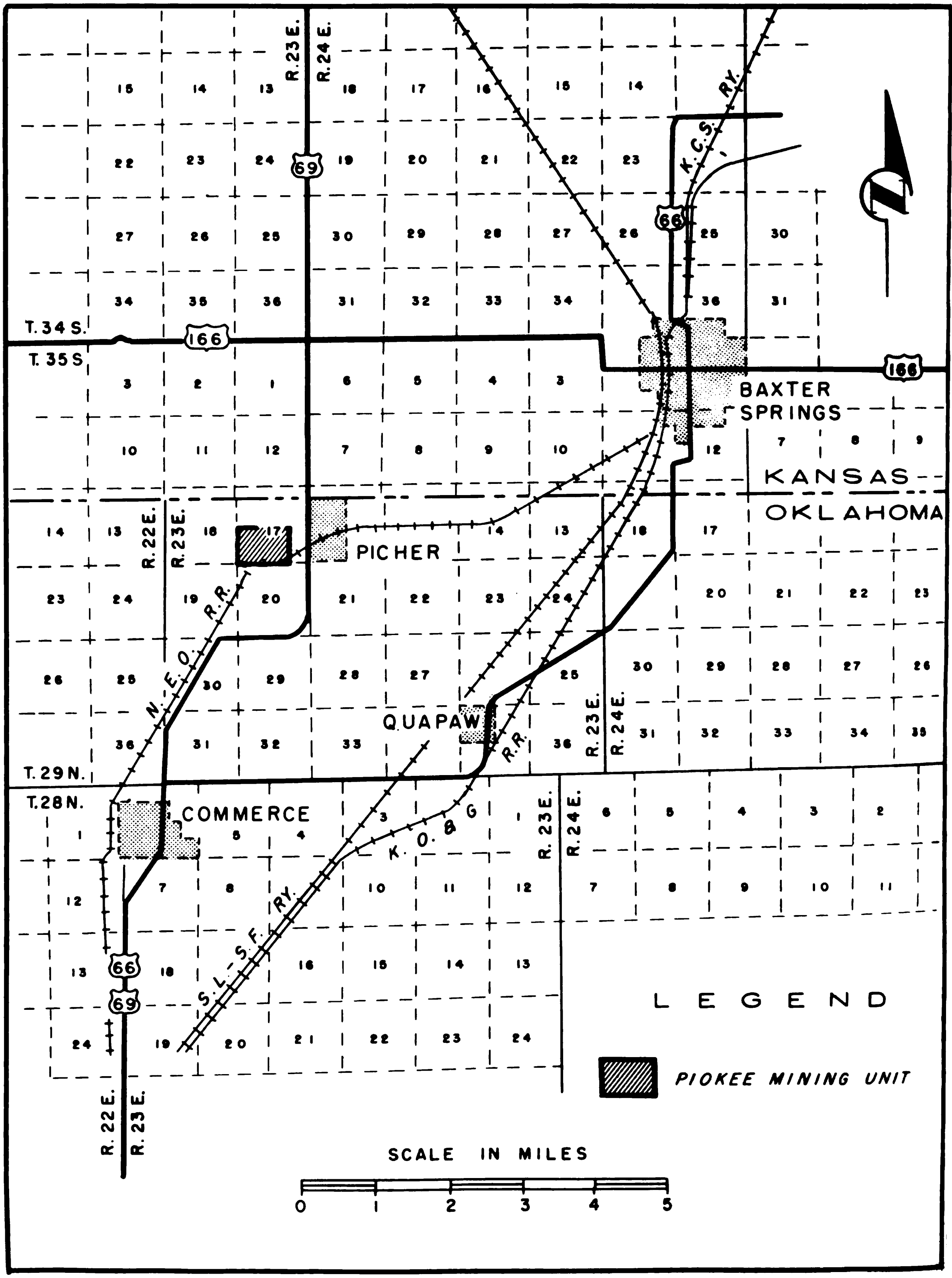

FIGURE 1. - Piokee Mining Unit, Ottawa County, Okla.

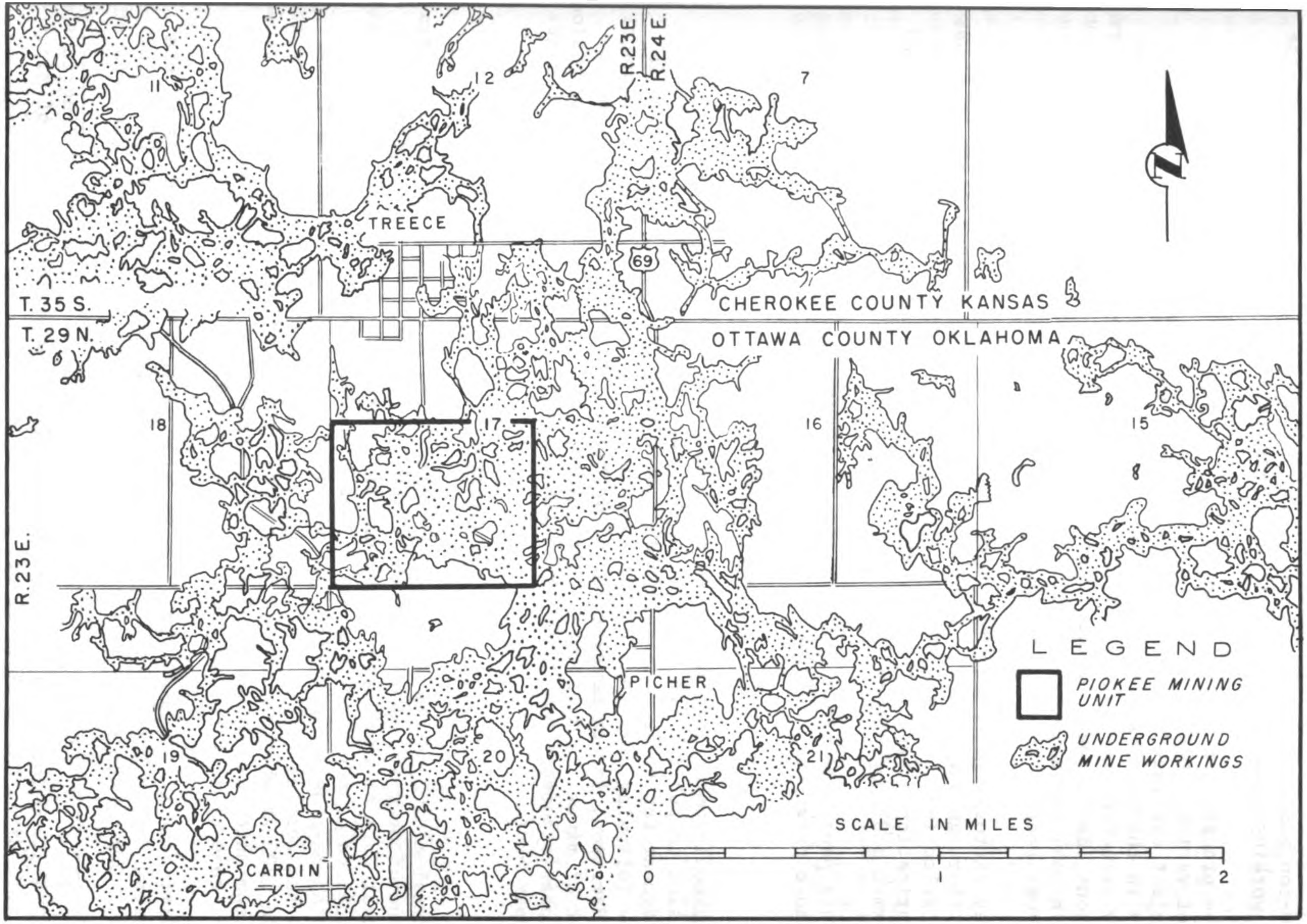

FIGURE 2. - Mines Map of North Central Part of Picher Field, Showing Piokee Mining Unit.

100,000-ton block of low-grade ore, which lay along the southern edge of the Piokee workings, was selected for the experimental mining.

The preparation phase of the project was begun in March 1957, but, because of various delays, full production did not begin until early in June. The project continued to the end of July 1957, when all operations of the company in the Tri-State district were suspended. Results of the experiment greatly exceeded expectations. The output per man per shift was an impressive 55.55 tons, an increase of more than 200 percent over the 16.88 tons obtained during normal operations in 1956. As a consequence, the cost of mining a ton of ore was reduced about 37 percent.

Key factors that made the project a success were: The high incentive bonus, thorough planning of all phases of the operation before production was begun, selecting the most suitable equipment, the rigid preventive-maintenance and lubrication schedule for equipment, and the cooperative spirit displayed by workmen and supervisors.

This paper describes the experimental project and compares the results with those previously obtained at the Piokee unit.

ACKNOWLEDGMENTS

Acknowledgment is made to The Eagle-Picher Co. for its cooperation and permission to publish the information and data in this paper. Special acknowledgment for their cooperation and assistance in preparing the data is due the following personnel of the company: F. J. Cuddeback, general manager; H. W. Harrison, former manager; L. E. Wetherell, assistant general superintendent of mines; R. K. Stroup, chief mining engineer; Andrew Kuklis, division mine superintendent; Ben Moody, land-lease agent; and members of the accounting department.

HISTORY

Metal mining in the Tri-State district (Missouri-Kansas-Oklahoma) covers a period of over 100 years, but the Picher, or Oklahoma-Kansas, field in the southwest part of the district was not discovered until 1914. Development and exploitation of the zinc-lead ore bodies proceeded rapidly on both sides of the Oklahoma-Kansas State line, and within a few years the area near Picher became the leading zinc-producing region of the world. Production reached its peak in 1925-26 when the 2-year output was over 28 million short tons of crude ore, from which nearly 1-1/2 million short tons of zinc concentrates and 1/4 million tons of lead concentrates were recovered.4/

Virtually all land on the Oklahoma side of the Picher field was within the Quapaw Indian Reservation and was allocated to the Indians in 200-acre tracts. During the early phases of mine development in Oklahoma, hundreds of

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4/ Martin, A. J., Summarized Statistics of Production of Lead and Zinc in the Tri-State (Missouri-Kansas-Oklahoma) Mining District: Bureau of Mines Inf. Circ. 7383, 1946, 67 pp.

individual operations were begun on small parcels of 20 and 40 acres, each of which, according to lease requirements, supported a separate mill. Royalty rates at first ranged from 5 to 25 percent of the sale price of both lead and zinc concentrates, but later, lessees could negotiate with the approval of the U. S. Department of the Interior for royalties not to exceed 12-1/2 percent.[5]

The first prospect holes on the Piokee 40-acre lease were drilled during the latter part of 1914, but it was not until 1916 that enough ore had been outlined to warrant shaft sinking. A mill was built on the property in 1917, and production was begun in 1918 by the Piokee Mining Co. The company reportedly mined and milled ore from the property in 1918 and 1920. No production was recorded in 1919. The mine was worked by the H. T. Mining Co. from 1921 to February 1926, then by Consolidated Zinc & Lead Co. until 1928, when operations ceased because of economic conditions.

The M & M Mining Co. acquired the property in 1941 and operated the mine until it was taken over by The Eagle-Picher Co. in April 1946. Thereafter, ore from the Piokee was commingled with ore from adjacent leases and hoisted through the Piokee shaft. Tables 1 and 2 show production data for the Piokee tract from 1918 to early 1946 and for the Piokee mining unit during the period 1946-57, respectively.

TABLE 1. - Production from Piokee tract, 1918-46

Years	Crude ore (short tons)	Concentrates (short tons)	
		Zinc	Lead
1918-20	67,873	1,252	1,229
1921-25	355,163	9,214	4,408
1926-27	32,811	1,001	424
1941-46[1]	301,462	17,532	2,955
Totals	757,309	28,999	9,016

[1] To April 1946.

TABLE 2. - Production from Piokee unit, 1946-57

Tracts	Crude ore (short tons)	Concentrates (short tons)	
		Zinc	Lead
Piokee	702,469	16,928	5,324
Howe	101,741	2,251	639
Lucky Syndicate	223,409	5,592	1,330
Otis White	19,250	511	130
Netta White	208,747	5,845	1,058
Totals	1,255,616	31,127	8,481
Ohimo[1]	2,929	50	27
Big Chief[1]	2,148	54	27
Crawfish[1]	7,853	163	68

[1] The designated quantities of crude ore from these tracts also were hoisted through the Piokee shaft but were not included in the production totals.

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[5] Elizondo, J. B., Development and Mining Trends in the Tri-State District: Univ. of Missouri School of Mines and Metallurgy Tech. Bull. 94, 1957, pp. 1-15.

DESCRIPTION OF DEPOSIT

The Picher field is at the west end of a mineralized belt that extends about 100 miles eastward to the vicinity of Springfield, Mo. The zinc-lead ore deposits occur mainly in the Osage series (Boone formation) of Mississippian age, which in the Picher field is obscured beneath an extensive blanket of Pennsylvanian Cherokee shale (fig. 3). The parent limestone beds were subjected to regional deformation and successive replacement by chert, dolomite, jasperoid, lead and zinc sulfides, and other minerals.

The ore deposits of the Piokee and vicinity are restricted mainly to what is locally known as upper-bed mineralization--the Warsaw formation (E and G-H beds), and the extreme upper part of the Keokuk (K bed). The minable beds are 160 to 235 feet below the surface, covering a vertical interval of about 75 feet (fig. 4). The mean altitude at the surface is 830 feet. The cap rock is black, incompetent shale of the Cherokee formation, which is about 90 feet thick in this part of the field. Underlying the Cherokee is 40 feet of Chester limestone, which was mineralized in places but rarely to ore grade.

The ore minerals are sphalerite and galena, which occur in the ratio of approximately 4:1. The galena content increases toward the outer limits of the ore bodies and in the upper beds in conjunction with fracture zones. The gangue consists of variable quantities of chert, cotton rock (partly silicified limestone), dolomite, jasperoid, and calcite. Ore in place has an average weight of about 4,400 pounds per cubic yard and broken ore about 2,700 pounds.

Ore bodies in the G-H beds are interconnected for the most part and average 30 to 40 feet in thickness. They tend to taper off, however, along the fringes to the upper 10 feet of the beds. A large part of the ore reserves remaining in the Piokee area is in these fringe areas. The tenor of this fringe ore is usually low, as the ore minerals are disseminated in alternating bands of chert and jasperoid. In contrast, the ore in the overlying 6 feet of E bed and the underlying 2 to 10 feet of K bed is more massive in character and is confined to narrow, isolated runs. These runs follow shear zones along dolomite-jasperoid contacts and are separated from the G-H beds by 10 feet of F-bed cotton rock and 1 to 10 feet of J bed (glauconite-speckled limestone), respectively.

METHODS OF PROSPECTING AND EXPLORATION

Churn drilling always has been the principal method of exploring for zinc-lead deposits in the Picher field. Diamond core drilling has been attempted but is not practicable because of the hardness and abrasiveness of the chert and jasperoid and the vuggy nature of the mineralized beds. Early prospecting usually was done in a haphazard manner in an attempt to prove quickly enough ore to warrant sinking a shaft. Lack of adequate and systematic drilling often resulted in early abandonment of the first shaft and the sinking of another shaft at a more suitable location. Drilling was often duplicated, owing to lack of communication between companies exploring both sides of common boundaries, lost or inadequate drill records of previous drill holes, or through failure to drill original holes deep enough to test all the ore horizons.

SYSTEM	SERIES	FORMATION	REMARKS
PENNSYLVANIAN	DES MOINES	MARMATON GROUP: PAWNEE LS. MARMATON FT. SCOTT LS.	*Ft. Scott limestone outcrops in Southeastern Kansas*
		CHEROKEE SHALE	*Cherokee shale is surface formation in the Picher field*
		Hiatus From CHESTER Sediments to Des Moines No Morrow Sediments Deposited	
UNCONFORMITY			
MISSISSIPPIAN	CHESTER	CHESTER LIMESTONE (MAYES) (CARTERVILLE)	*Very irregular in thickness and often missing in the Picher field*
	MERAMEC	"B" BED LIMESTONE	*Probably occurs as local lenses and pockets in Picher field*
	OSAGE	WARSAW	*C thru J beds = Warsaw* *J bed is Cowley Form. in S.E.Kans.* *All Osage sediments in this area are referred to in some literature as Boone formation*
		KEOKUK	*K thru Q beds*
		REEDS SPRING	
		FERN GLEN	*St. Joe limestone is basal Fern Glen and therefore basal Boone*
	KINDERHOOK	NORTHVIEW	*Shale*
		COMPTON	*Limestone*
Major Hiatus From Lower Ordovician Sediments to Basal Mississippian With the Exception of Local Lenses and Pockets of Chattanooga (Devonian) Shale			
UNCONFORMITY			
ORDOVICIAN	BEEKMANTOWNIAN (CANADIAN)	COTTER DOLOMITE	
		JEFFERSON CITY DOLOMITE	
		ROUBIDOUX	
		GASCONADE	
		VAN BUREN	
		GUNTER SANDSTONE	
CAMBRIAN	OZARKIAN	PROCTOR	*Not present in Picher field?*
		EMINENCE DOLOMITE	
		POTOSI	*Not present in Picher field?*
	UPPER CAMBRIAN	BONNETERRE DOLOMITE	
		LA MOTTE SANDSTONE	
UNCONFORMITY			
PRECAMBRIAN IGNEOUS AND METAMORPHICS			

FIGURE 3. - Geologic Column, Picher Field.

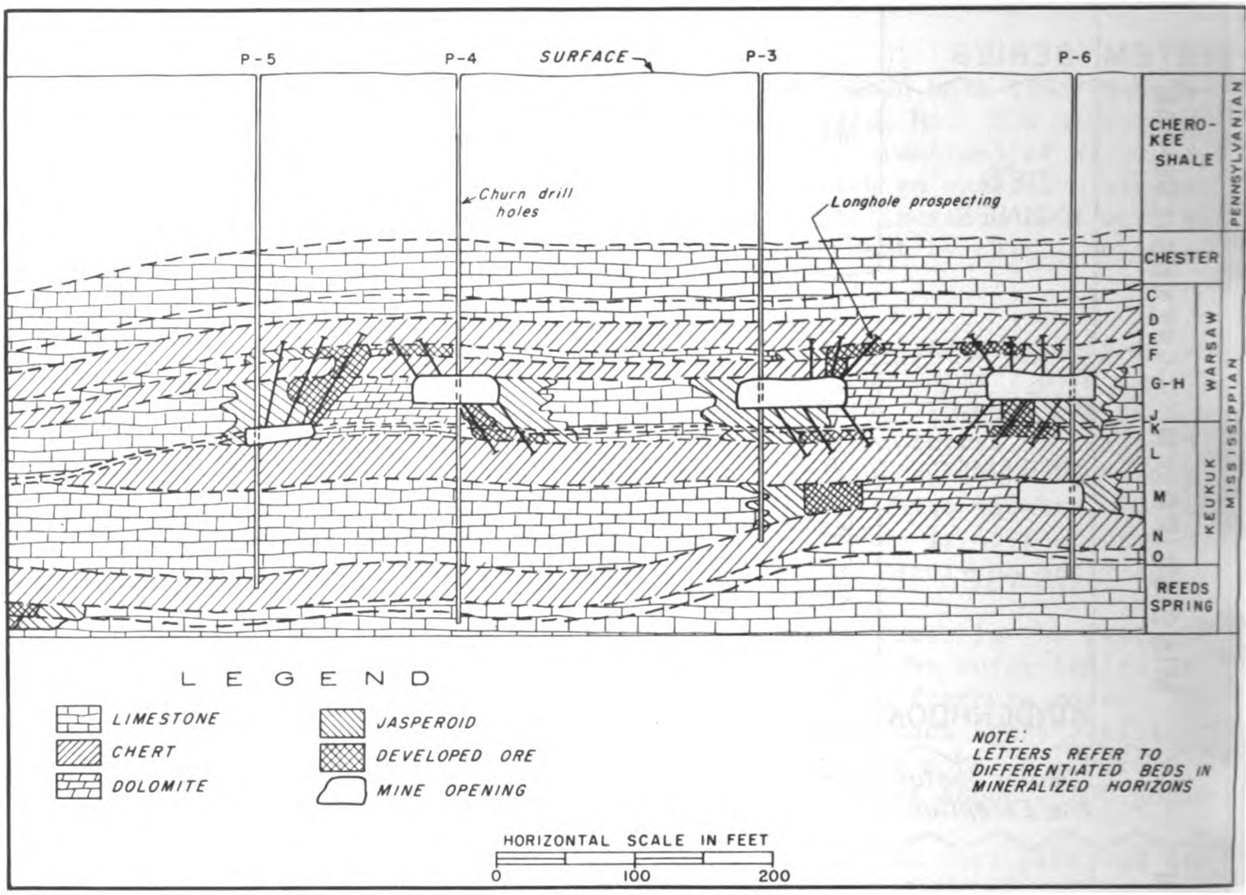

FIGURE 4. - Schematic Geologic Section, Piokee Mining Unit.

During the past 20 years, churn drilling has been used much more effectively. For example, structural contouring of certain key horizons from churn-drill information has disclosed the relationship of many ore bodies to anticlinal structures.6/ The understanding and significance of areal stratigraphy--especially the recognition of critical beds from drill cuttings--also have led to more effective spotting of drill holes with respect to discovering and outlining ore bodies. Such drilling is classed locally as development.

Churn drilling has been augmented in recent years by underground longhole drilling. Holes were drilled from underground stations with percussion drills to explore for ore bodies above and adjacent to mine workings.7/ Longhole drilling was used also to outline the vertical and lateral extensions of known

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6/ Lyden, J. P., Aspects of Structure and Mineralization Used as Guides in the Development of the Picher Field: Min. Eng., December 1950; Trans. AIME, vol. 187, December 1950, p. 1254.

7/ Clark, S. S., and Brockie, D. C., Jackleg Drilling in the Tri-State District: Longhole Prospecting and Production: Min. Eng., January 1956, pp. 27-30.

re bodies. The jackleg drill has been used successfully, but because of its imitations was superseded by the standard production drifter and deep-hole ercussion drills. Standard crawler jumbos and converted obsolete diesel oaders were used most successfully as mountings for these drills. Horizontal nd slightly uptrending holes have been drilled to depths of 250 feet and ver- ical holes to more than 100 feet. Drill cuttings were collected in 5-foot ntervals and logged by experienced personnel. Locations and all other perti- ent data were recorded on geological maps for use in planning further drill- ng and mine development.

METHODS OF SAMPLING AND ESTIMATION OF TONNAGES AND VALUES

Batch shipments to the company's Central Mill were weighed and sampled to etermine values of the shipments, royalty settlements, and metallurgical con- rols. At mining units where ores were commingled--combined from two or more eases into one batch shipment--truck and can counts were used to determine he proportions of the shipment to be credited to the various leases.

Visual estimates were made regularly of the percentages of recoverable inc and lead sulfides in the mine faces. Mine superintendents and foremen ave become surprisingly accurate in estimating ore grades. Knowing the break- even grade of ore from current costs of production and values per ton of con- centrates, they could determine readily whether a face contained minable or submarginal ore.

Visual estimates also were made by the Geological Department in logging churn-drill and longhole-drill cuttings; however, when the estimated mineral content exceeded 1 percent combined lead and zinc sulfides, samples were taken for chemical analysis.

METHODS OF DEVELOPMENT AND MINING

Development

Underground development in the Picher field during its early history seldom was based upon long-range planning. Vertical shafts were sunk to one or more ore zones, and most of the underground development that followed was an integral part of the mining operation. As mining progressed, it became ecessary to drive raises, inclines, and crosscuts (locally called pull drifts) etween ore bodies to facilitate the movement of ore. Crosscuts were driven also to test areas where churn drilling had indicated ore possibilities. The crosscuts were originally 7 by 7 feet in section but were enlarged later to 12 feet in height and 14 feet in width to facilitate truck haulage.

Nineteen shafts once were used for hoisting ore or men and supplies at he several 40-acre leases that now are included in the Piokee mining unit of approximately 200 acres. Most of the shafts are now caved or sealed, but a few are kept open for ventilation. The present hoisting shaft, which is on he Piokee 40-acre tract (fig. 5), originally was sunk to a depth of 200 feet. This shaft, 6 by 6 feet inside, was cribbed with 2- by 6-inch fir lumber hrough the shale formation from the collar to a depth of 88 feet.

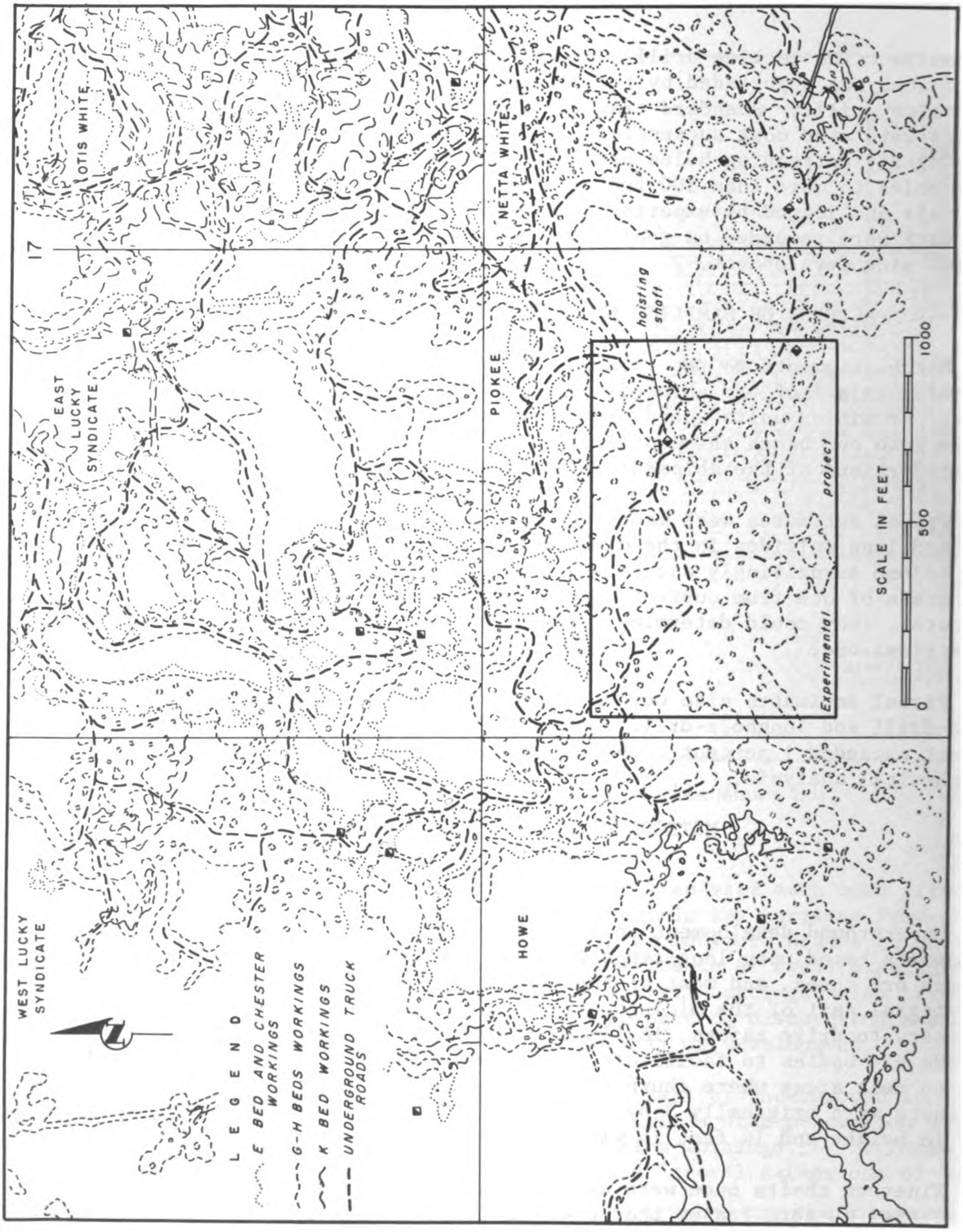

FIGURE 5. - Plan of Underground Workings, Piokee Mining Unit.

Mining

The open-stope method of mining, with and without natural pillar support, has been used universally throughout the Tri-State district since underground mining of its zinc-lead ores was begun. Some relatively narrow run-type ore bodies with competent roofs were mined without pillar support, but most of the ore occurred in deposits of considerable lateral extent where pillars were required for roof support as mining progressed. Originally, about 12 percent of the ore in these deposits was left in the pillars. In recent years, under close supervision, a considerable part of the ore in these pillars has been recovered.

Drilling

Approximately 50 percent of the ore produced during 1956 in the Piokee unit was mined from run-type deposits, and much of this ore was in the K bed, which lies immediately below the original mine floor. These runs, which are 5 to 10 feet deep, were mined in trenchlike fashion. Four crawler-type twin-boom jumbos, each mounting two 3-1/2-inch chain-feed drifters (fig. 6), were used for drilling the blasthole rounds. Holes were drilled horizontally 10 feet deep and spaced so that the burden on each did not exceed 6 feet vertically or laterally.

The remainder of the ore produced in 1956 was mined from beds in and above the original roof of the mine. A jumbo with telescoping mast, extendable to a maximum length of 35 feet (fig. 7), was used for drilling most of the roof ore. The mast is mounted on a standard Eagle-Picher crawler base, which carries a 1-ton counterbalance on the rear end to stabilize the unit. The drilling crew for this jumbo consisted of two men--a driller and a helper. The ore was undercut in 5- to 10-foot stages, depending on the thickness of the ore zone and the nature of the bed forming the temporary roof. By carefully spacing the blastholes, large tonnages of ore were broken per machine shift with fair fragmentation.

Drill steel was processed in a central surface shop at Cardin, Okla., where close temperature control was maintained in gas-fired furnaces to assure proper heat treatment of shanks and threads. The drill steel was cut into 12-foot lengths from low-carbon, 1-1/4-inch hollow round stock. Facilities for manufacturing tungsten-carbide-insert drill bits and truck springs were added recently to the shop.

During 1956 the Piokee unit used 650 detachable 2-5/8-inch tungsten-carbide-insert bits. The unit costs for bits and steel were $0.098 per foot drilled and $0.059 per ton of ore produced.

Blasting

Semigelatin dynamite of 40-percent (bulk) strength was used for blasting in 1955 and the first 8 months of 1956; 47-percent ammonia dynamite was used thereafter. The explosives charges were detonated with No. 6 blasting caps and trimmed safety fuse. The average consumption of explosives in 1956 was 0.67 pound per ton of ore broken. Little secondary blasting was required.

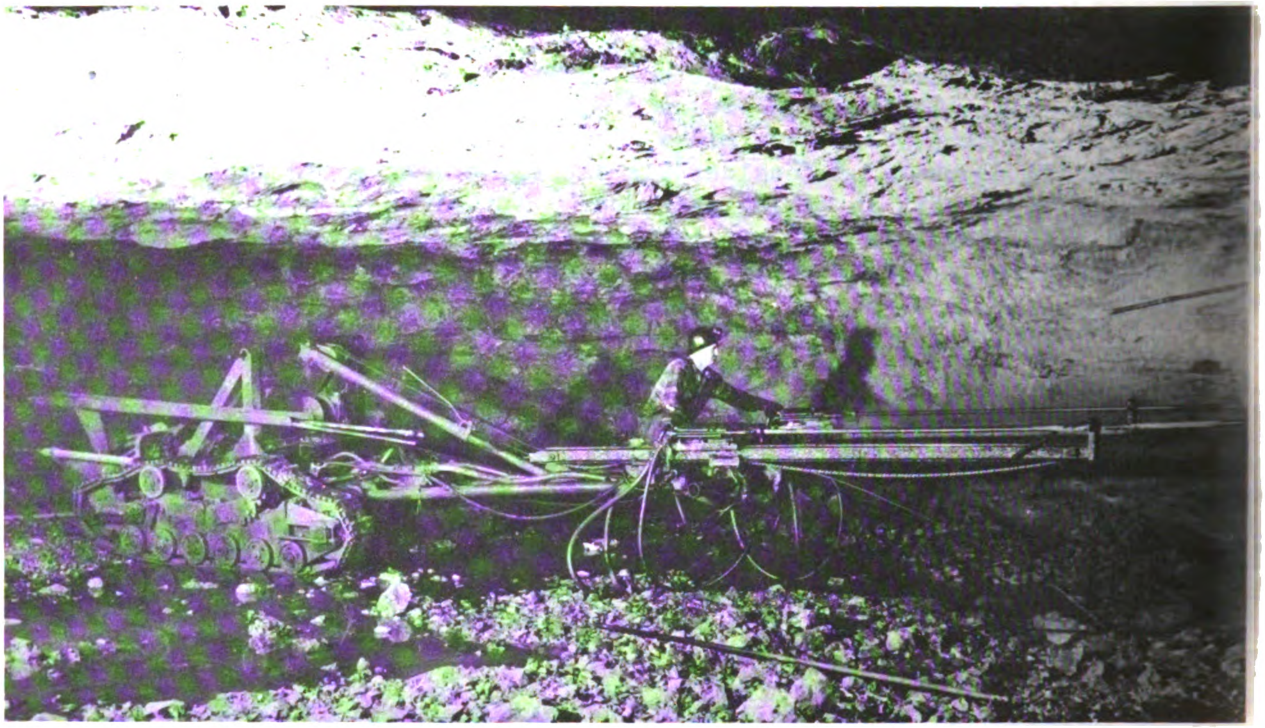

FIGURE 6. - Crawler-Type Twin-Boom Drilling Jumbo.

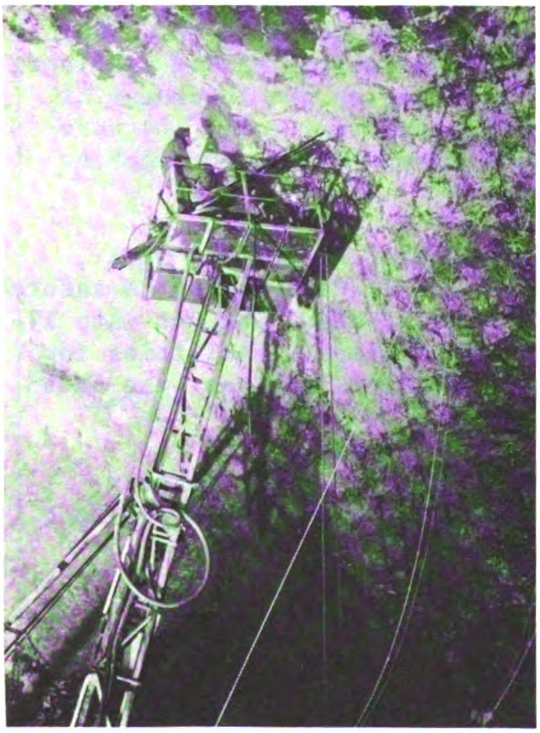

FIGURE 7. - Drilling From Platform on Telescoping Mast.

Loading

Enough headings (faces) were worked to insure that ore breaking would be one or more shifts ahead of loading operations. Nearly 63 percent of the ore produced in 1956 was loaded into trucks underground with two diesel-powered machines--one front-end loader and one overshot loader. The remainder of the ore was loaded with three Eagle-Picher crawler ramp-type slushers (fig. 8).

The types of loaders used and tonnages loaded by each in 1956 are shown below:

	Total tons loaded (wet)
Type of loader:	
Front-end (1)...............	39,303
Overshot (1)................	38,344
E-P crawler ramps (3).......	46,817
Total....................	124,464

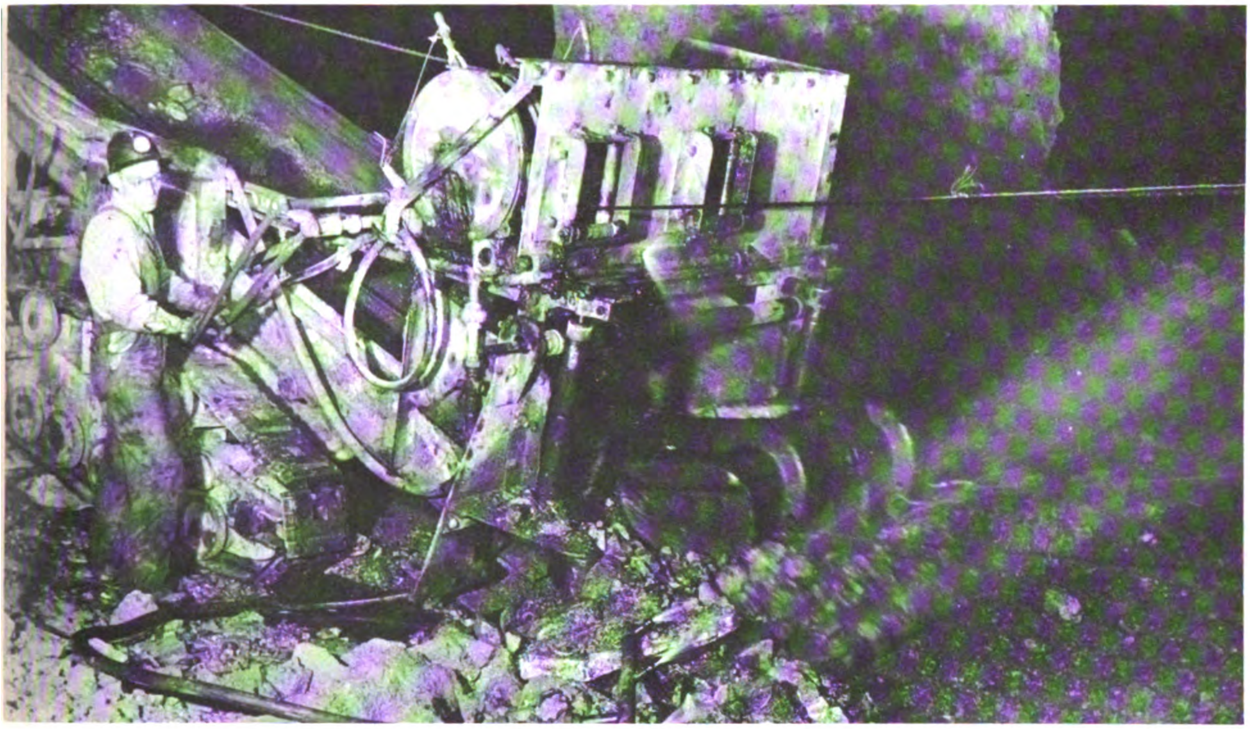

FIGURE 8. - Eagle-Picher Crawler Ramp-Type Slusher.

Underground Transportation

The ore-haulage equipment used in the Piokee unit in 1956 consisted of three 10-ton diesel-powered dump trucks and one diesel semitrailer truck. Three trucks usually were operated each shift, and one was held in reserve. A 1/2-ton pickup truck was used to transport supplies and personnel.

The average number of round trips and the quantity of ore hauled per truck per shift were 16.3 and 130 tons, respectively. The average distance from loader to hoisting shaft was about 1,500 feet, and the longest haul about 2,000 feet.

The underground road system has many curves and some grades as high as 15 percent. Roads were surfaced with coarse mill tailing and graded periodically with a diesel-powered grader.

Ore was dumped from the trucks onto a drive-over grizzly, through which all material up to 14 by 25 inches passed to the hopper below. Two screen men broke oversize boulders of ore with 12-pound mauls. The hopper has a capacity of 60 tons and was built of 8- by 8-inch rough fir and 2- by 12-inch green oak. The bottom has a pitch of 9 inches in 12 and is lined with 1/2-inch steel wear plate.

Hoisting

Ore was transferred from the hopper through a chute into cans for hoisting. The cans are 33 inches in diameter, 34 inches deep, and built of 10-gage steelplate. An air-actuated shuttle car moved the cans back and forth from the chute lip to the center of the shaft.[8] Two cans were used in the loading and hoisting cycle; while one was being filled with ore, the other was hoisted to the surface, dumped, and returned to the bottom of the shaft. The time required to complete the cycle was about 30 seconds. One man (hopper puller) controlled the filling of cans by means of a lift gate mounted over the chute, and another (hooker) operated the shuttle car, disengaged the cable hook from the empty can, and attached the hook to the loaded can for hoisting (fig. 9).

Ore was hoisted at the Piokee shaft with a friction-type hoist, powered by a 112-hp., 3-phase, 220-volt electric motor. The hoist is mounted in a steel derrick about 50 feet above the collar of the shaft (fig. 10). The cans dumped directly into a 400-ton storage hopper, from which the ore was transferred into railway gondolas at the end of each shift, or as required, for transport to the Central Mill.

The hoisting cable is 3/4-inch, 7 by 18 nonspinning steel-wire rope which usually was replaced after hoisting about 50,000 tons. A rope speed of 2,044 feet per minute was maintained while hoisting ore, whereas 500 feet per minute was the maximum allowed while raising or lowering personnel.

Auxiliary Operations

An underground shop, about 200 feet southeast of the hoisting shaft, was maintained for servicing equipment and making minor repairs (fig. 11). All major repairs were made in a well-equipped central machine shop and garage, near the company administrative, mining, and geologic offices at Cardin. All drilling jumbos and slusher-ramp loaders were fabricated in these surface shops.

Two interconnected surface compressor plants supplied compressed air to 10 Eagle-Picher mining units, including the Piokee. One plant, 3/4-mile west of Cardin, is equipped with four compressors with a combined capacity of 9,700 c.f.m. of air at a pressure of 110 p.s.i. The other plant, half a mile east-southeast of the Piokee, contains five compressors with a combined capacity of 5,400 c.f.m. of air at a pressure of 110 p.s.i.

A network of 8- and 6-inch surface lines carried the compressed air to various shafts or churn-drill holes, through which it was delivered to the mines. Underground, the compressed air was distributed to the headings in 3- and 2-inch lines and reached the drills at a pressure of about 85 p.s.i.

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[8] Netzeband, W. F., Mining Methods and Costs at the Rialto Mine, Nellie B Division, American Zinc, Lead & Smelting Co., Ottawa County, Okla.: Bureau of Mines Inf. Circ. 7823, 1958, pp. 15-18.

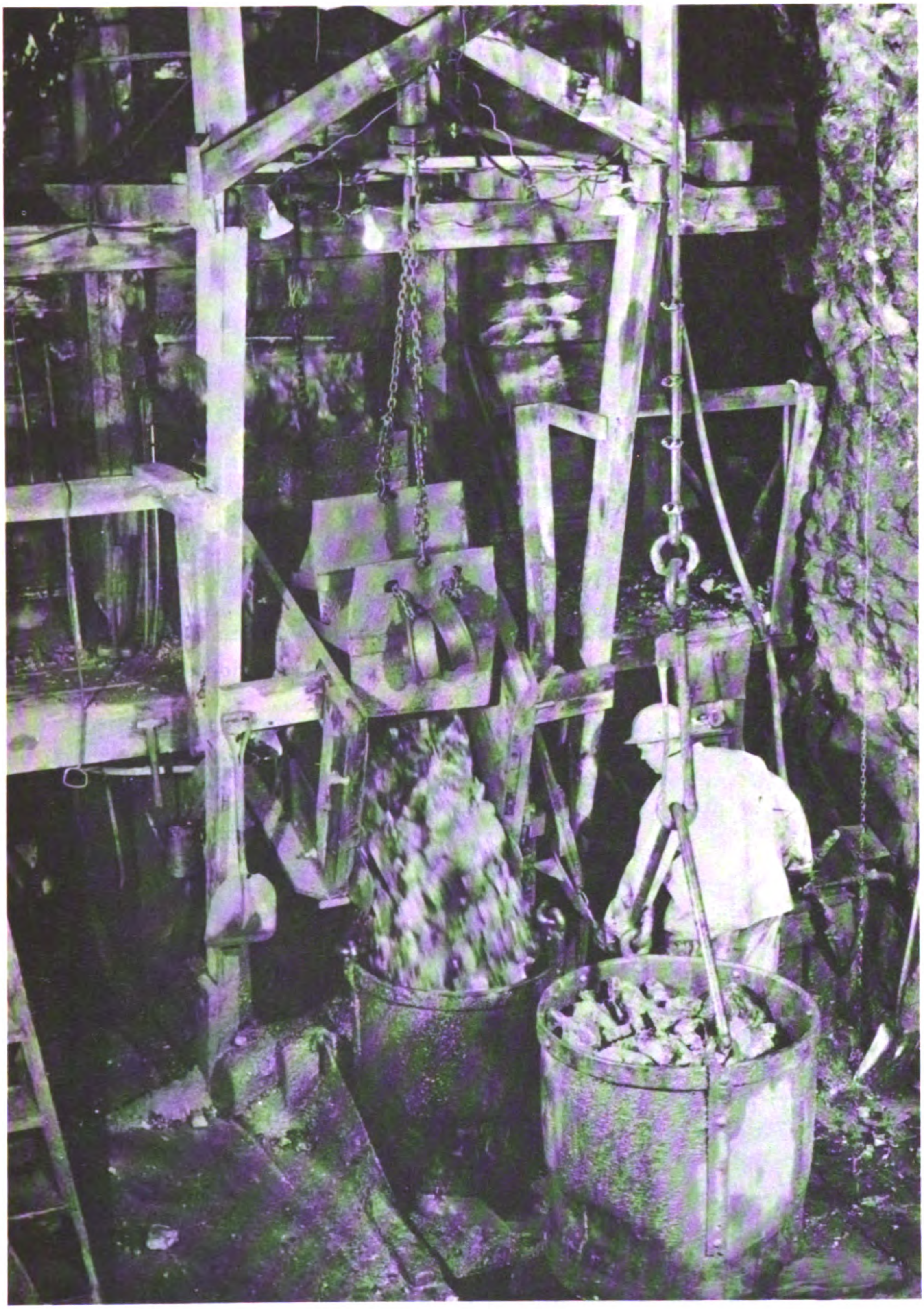

FIGURE 9. - Can Loading at Bottom of Hoisting Shaft.

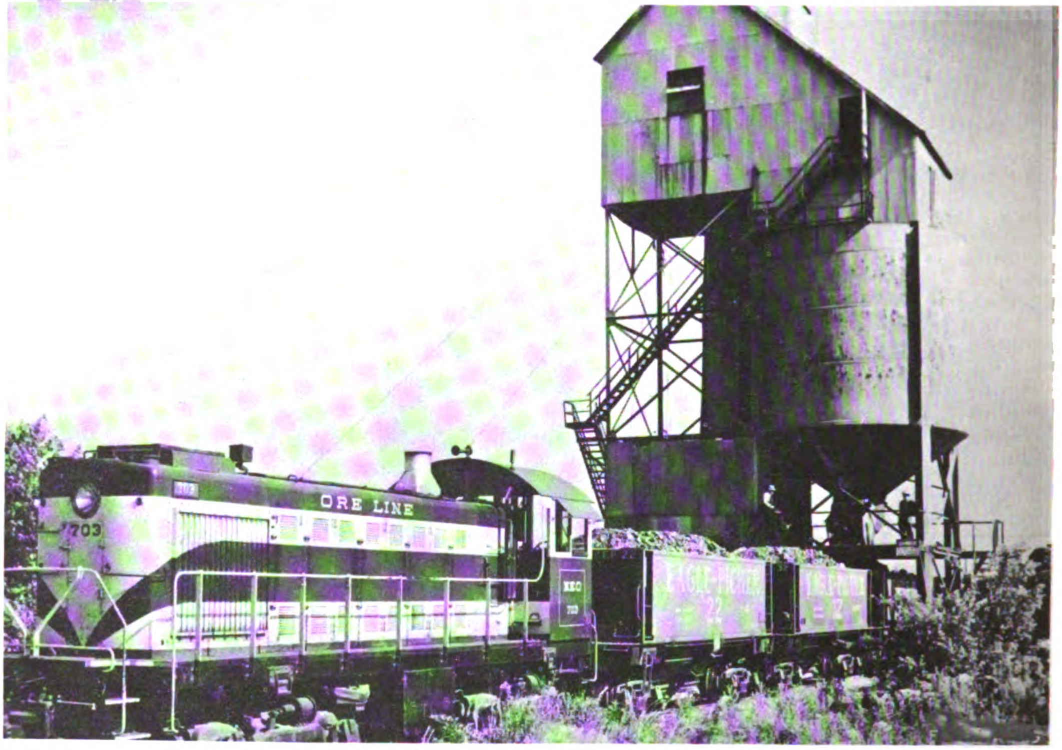

FIGURE 10. - Steel Hoisting Derrick and Storage Hopper.

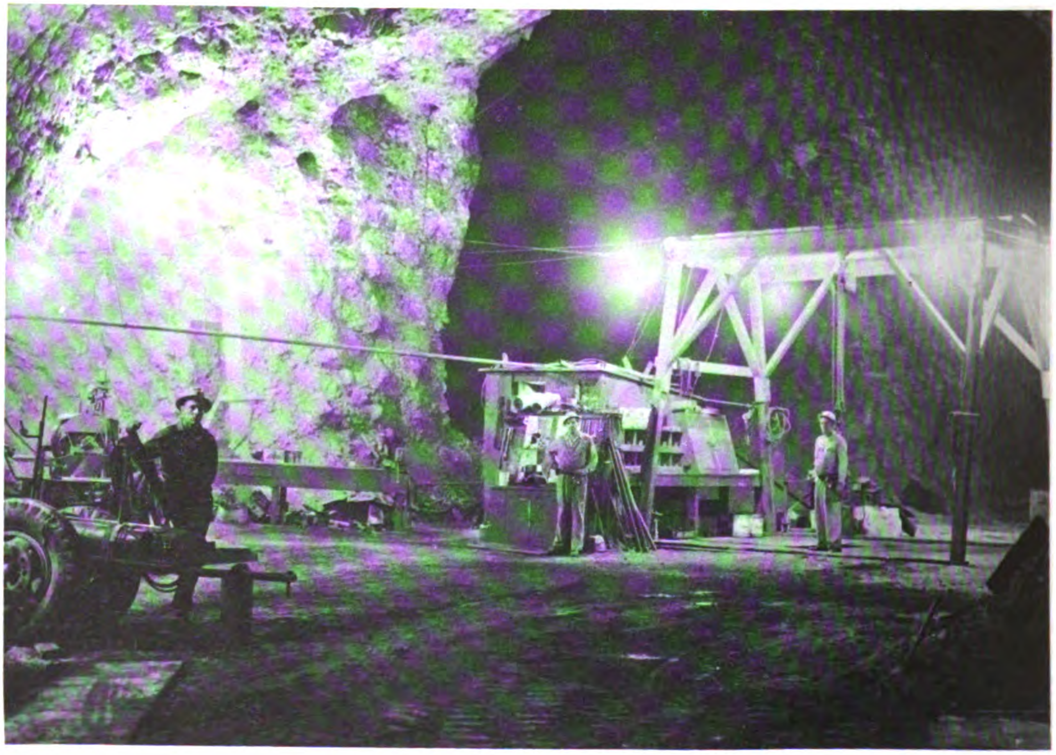

FIGURE 11. - Underground Shop.

Water for drilling at the Piokee unit was supplied from two surface ponds by gravity flow through 3- and 2-inch pipelines. The differential of plus-200 feet in elevation produced a water pressure of approximately 100 p.s.i. in the mine.

Electric power was supplied by the Empire District Electric Co. from its generating plant at Riverton, Kans. Alternating current at 25 cycles was transformed from 2,300 to 220 volts for use at the mine.

PERCENT EXTRACTION AND PRODUCTION RATES

Approximately 88 percent of the minable ore has been extracted from ore bodies where pillars were left for support. Much of the ore remaining in the pillars probably will be recovered ultimately. Nearly 100-percent extraction is obtained from narrow, run-type deposits.

The Piokee mining unit produced 120,107 dry short tons of ore from December 1, 1955, to November 30, 1956 (Eagle-Picher Co. fiscal year). The unit operated one shift per day, 6 days a week, producing ore at an average rate of 389 tons a day. Mill recoveries of zinc and lead concentrates averaged, respectively, 2.85 and 0.57 percent, by weight, of the crude ore milled (recoveries expressed in terms of 60 percent zinc content and 80 percent lead content of the respective concentrates).

VENTILATION

Natural draft through the open shafts and the wide expanse of interconnected workings supplied most of the ventilation required. A 15-hp. blower, installed at the collar of a shaft near the southwest corner of the Netta White lease, was used for auxiliary ventilation, exhausting 43,000 c.f.m. of air through the shaft.

In narrow headings and in raises forced draft was supplied through churn-drill holes with high-pressure blowers installed at the surface. These blowers, driven by 5-hp. electric motors, forced approximately 2,000 c.f.m. of air through the average 6-1/4-inch-diameter, 200-foot drill hole.

The temperature in the mine is fairly constant at 70° F. throughout the year.

MINE DRAINAGE

The mine workings in the Piokee unit are relatively dry, as all mining has been limited to the upper beds of the ore-bearing Boone formation. A 1-1/2-inch centrifugal pump at the shaft sump was operated occasionally as required.

WAGE AND BONUS SYSTEM

Wages paid to the mine crew were based primarily upon established hourly rates as set forth in a contract between The Eagle-Picher Co. and the United Steelworkers of America. The classification and composition of the average crew and the hourly rates are shown in table 3.

TABLE 3. - Labor classification and wage rates, 1956

	Classification	Hourly wage rate 1/		Classification	Hourly wage rate 1/
1	Foreman....................	(2/)	1	Semitrailer truckdriver....	$1.52
1	Herder (assistant foreman).	$1.63	1	Welder and maintenance man.	1.57
5	Machinemen.................	1.55	1	Diesel mechanic............	1.60
1	35-ft. jumbo machineman....	1.75	1	Hoistman...................	1.63
1	35-ft. jumbo helper........	1.68	1	Hooker.....................	1.63
2	Powdermen and roof trimmers	1.55	1	Hopper puller..............	1.42
2	Slusher ramp operators.....	1.55	2	Screenmen..................	1.42
2	Diesel-loader operators....	1.58	1	Mine serviceman............	1.90
2	Dump-truck drivers.........	1.49	1	Mine service helper........	1.83

1/ Hourly rates were based upon a 40-hour week. Actual rates for the full 48-hour week were 52/48 of the rates listed.

2/ On salary.

In addition to the set wage each man on hourly rate engaged in production participated in an incentive bonus plan. Mine service employees were excluded from participation. This bonus plan, which is part of the contract with the union, was based upon average output per man per shift above a predetermined standard. Each participant received a bonus of $1.25 per week for each wet ton of ore produced per man per shift in excess of the standard or base. The base at the Piokee in 1956 was 11 tons per man per shift. The average bonus earned by each man was 25.6 cents an hour, or 10.1 cents per ton. A typical bonus computation is shown in table 4.

TABLE 4. - Bonus computation, week ending August 19, 1956

3,184 (cans hoisted)	x	0.790 (average wet weight per can)	=	2,515 (tons for week)
2,515 (tons for week)	÷	129 (bonus man-shifts for week)	=	19.50 (average tons per man-shift)
19.50 (average tons per man-shift)	-	11.00 (base tons per man-shift)	=	8.50 (bonus tons per man-shift)
8.50 (bonus tons)	x	$1.25 (bonus rate per ton)	=	$10.63 (bonus per man--6 days straight time)
(6.5 ÷ 6)1/	x	$10.63	=	$11.52 (weekly bonus--6 days plus overtime)

1/ Weekly bonus calculated on basis of 1-1/2 days for the 8 hours worked in excess of 40 hours.

SAFETY AND HEALTH

Company-sponsored programs promoting mine safety have been in effect for over 30 years. Early efforts eliminated such practices as blasting on shift, dry drilling and shoveling, and operating single-entry mines without adequate natural or forced ventilation.

In 1942 Eagle-Picher established a department of industrial hygiene, functioning under the safety department, to study the dust problem and resolve methods of eliminating or reducing it. Hundreds of dust counts were made throughout the mines, and various corrective measures were taken to reduce the dust hazard. For example, the practice of using dust-contaminated mine water in sprays was quickly eliminated after discovering that the water, in one instance, contained 11 billion micron-particles of dust per gallon. Later, the department tested the air underground regularly for oxygen content and the presence or absence of hydrogen sulfide, methane, carbon monoxide and dioxide, oxides of nitrogen, and aldehydes. The design and inspection of diesel-exhaust scrubbers and the effective use of ventilating fans and blowers were other responsibilities of the department.

Roof bolting was used successfully as early as 1945, but its application has been limited to haulageways, shop areas, and other frequented places. An 8-gage industrial gun was used to advantage by the safety department in high-roof areas where trimming formerly was done from the tops of multiple-section ladders.

EXPERIMENTAL PROJECT

Preparation Phase

Until the spring of 1957, the Piokee mining unit was operated in the same manner as the other 14 units of Eagle-Picher's Tri-State operations; controlling the grade of ore was of primary importance and was accomplished by selective mining. Management realized that the life spans of several units, including the Piokee, were rapidly nearing an end unless the low-grade reserves could be mined at a profit. The outlook for mining this low-grade ore did not appear promising when its net value was compared with probable mining costs under existing efficiency standards.

The company decided to conduct an experiment in the spring of 1957 to determine what could be achieved toward increasing mining efficiencies if most of the key factors governing optimum operating conditions were stipulated. A 100,000-ton block of low-grade ore in the G-H beds was selected for mining under carefully controlled conditions, using the most suitable equipment and facilities at hand. This block of ore lay along the edge of the mine workings about 500 feet southwest of the Piokee hoisting shaft (fig. 12).

The designated ore block was to be mined by the room-and-pillar method, with a minimum roof height of 12 feet to accommodate the loading and hauling equipment. The main zone of ore mineralization in this block is confined to about 5 feet of the beds and is composed of disseminations of zinc and lead

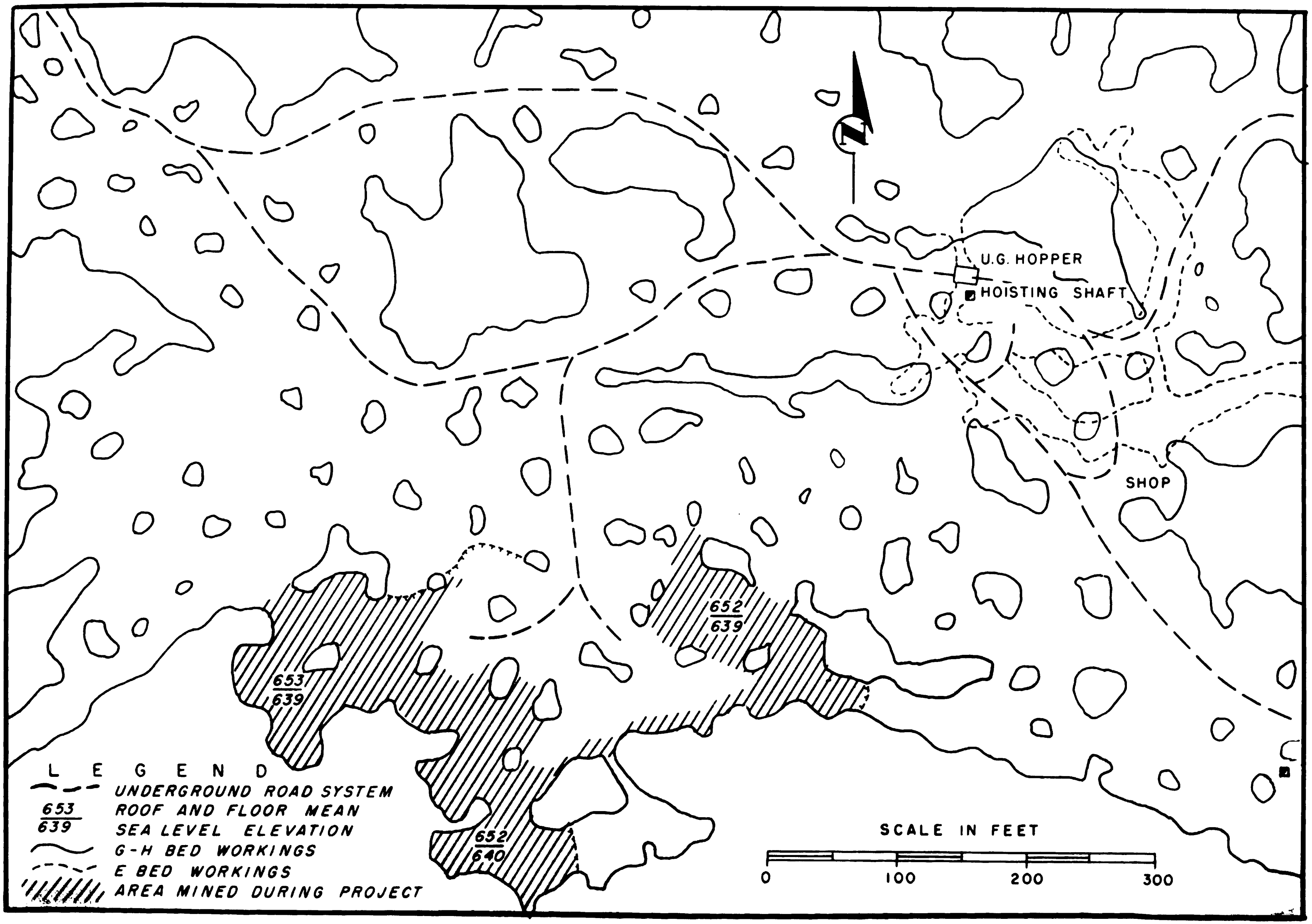

FIGURE 12. - Map of Part of Piokee Underground Workings, Showing Area of Experimental Mining.

sulfides in banded chert, which lies immediately below a partly chertified limestone member, known locally as cotton rock. As this member is less competent than most in the Boone series, pillar spacing was to be limited to a maximum of 40 feet. Below the main ore zone the chert graded into barren limestone.

Output was to be regulated by hoisting capacity based upon one 8-hour shift per day, 6 days a week. The equipment selected for the experimental mining project included four overhauled crawler-type, twin-boom jumbos, each mounting two 3-1/2-inch chain-feed drifters; one new 2-cubic-yard, diesel-powered, rubber-tired front-end loader;[9] two overhauled 15-ton trailer trucks; and one 3/4-ton pickup truck for maintenance use. One crawler-type front-end loader and one 12-ton trailer truck were selected as standby units.

Selecting a crew for the project was a much greater problem than the choice of equipment, as the company adhered closely to the union contract. The various jobs were posted for "bid," and the ultimate selection was based upon seniority and qualifications. Operational plans indicated that a crew of 11 men, including a mine foreman, was needed to maintain production at the expected rate. The makeup of the crew and base hourly rates are shown in table 5.

TABLE 5. - Labor classification and wage rates for experimental mining project, 1957

	Classification	Hourly base wage
1	Mine foreman	(1/)
1	Diesel mechanic--leadman	$1.805
3	Machinemen (drillers)	1.63
1	Powderman--roof trimmer	1.63
1	Diesel loader operator	1.66
1	Trailer truckdriver	1.60
1	Hoistman	1.71
1	Hooker	1.71
1	Combination maintenance-hooker-truckdriver	1.65

1/ On salary.

A bonus plan similar to the one established for regular production operations was to be used as an incentive to high productivity. The base tonnage per man per shift was set at 20 tons, which would give each man a bonus of $20 a week if output averaged 35 tons per man per shift.

During the planning phase, the concensus was that ore breaking would require three jumbos, each operated by one machineman. The truckdriver would operate the two 15-ton trailer trucks, driving one to the shaft and back while the other was being loaded. The "combination" man was to help where needed and substitute for any absentee.

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[9] Dale, Claude O., Underground and Ore Loading Equipment: Min. Cong. Jour., October 1957, p. 105.

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Considerable underground preparation was required before experimental mining could proceed, including installation of air and water lines, preparation of roads, and overhaul of the underground hopper, shaft facilities, and mining equipment. The overhauling and reconditioning of equipment required considerable time and capital outlay, but thorough inspection of each machine and replacement of worn parts were necessary to avoid possible breakdowns. Roof heights in the project area were too low for efficient use of equipment, so the floor was taken up and enough faces prepared to permit the desired cycling of ore breaking and loading.

The preparation phase of the project was begun on March 11, 1957, when the Piokee unit was still on normal production. The preparatory work at first proceeded so that it did not impede or curtail main output but was accelerated rapidly after April 6 when regular production was halted. Enough progress had been made by April 22 so that partial production from the selected block of low-grade ore was begun immediately. The project was suspended from April 28 to June 3 during a general shutdown of Tri-State operations, but the brief period of operation provided an opportunity to test some of the equipment and check the grade of ore by lot shipment.

Test Period

The Piokee project went into full production early in June 1957 when Tri-State mines of The Eagle-Picher Co. resumed operations. Daily output averaged 583 tons of ore in June and 596 tons in July. All phases of the project functioned smoothly; moreover, it soon became apparent that the three machine men, with the use of only two jumbos, would break more than enough ore to keep the hoist operating at full capacity. Near the end of the 2-month test period so much broken ore had accumulated that output was maintained for several days without further drilling and blasting. Slab rounds were drilled[10] with shop-built 2-3/8-inch carbide-insert bits and 1-1/4-inch round, low-carbon drill steel in 12-foot lengths. The holes were loaded with 47-percent ammonia dynamite, and the charges detonated with No. 6 caps and safety fuse. Fragmentation was such that little secondary breaking was needed at the drive-over screen (grizzly) above the underground shaft hopper. An electric warning system was installed to notify the shop man when assistance was needed at the grizzly.

The rubber-tired front-end loader and one 15-ton trailer truck proved to be ample for loading and hauling (fig. 13), so the second truck was used only as a standby. The other loader and the 12-ton truck originally selected as reserve equipment were not needed. A rigid preventive-maintenance and lubrication schedule was set up and followed for each diesel-powered unit. Breakdowns were minor and in no instance caused a serious delay.

The hooker, in addition to his customary duties, filled the 3/4-ton can from the underground hopper by means of an air-actuated chute gate. This operation previously was done by a hopper puller.

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[10] Work cited in footnote 8, p. 14.

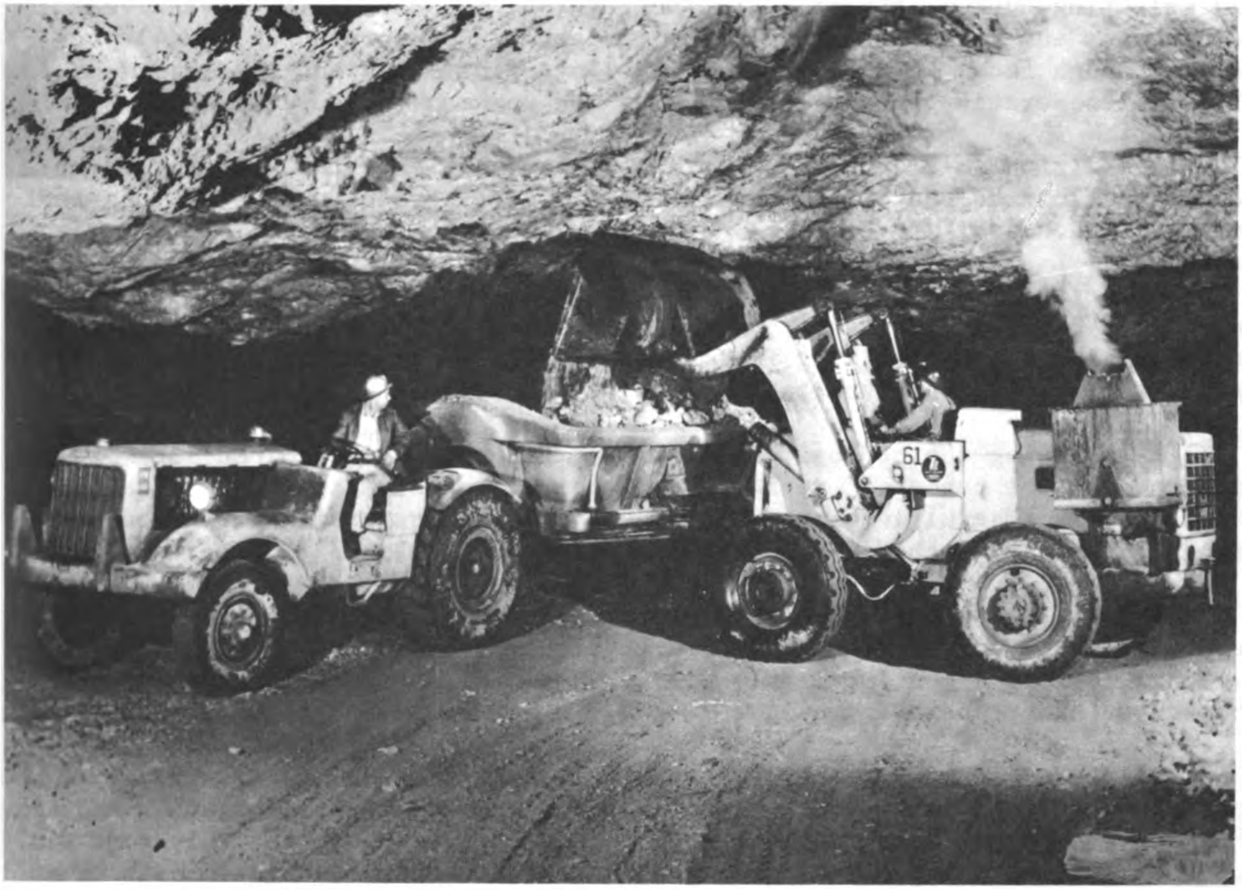

FIGURE 13. - Rubber-Tired Front-End Loader and 15-Ton Trailer Truck.

The workmen were pessimistic at first as to the possibility of maintaining an average output of 35 tons per man per shift, but after the first few weeks of production their attitude changed to that of optimism and a desire to excel. Little or no "bumping" was done at first, but eventually it became a problem as increasingly larger bonuses were earned.

Results and Conclusions

The experimental mining project exceeded expectations. It was evident after the first few weeks of operations that the incentive bonus, which grew to three times the amount anticipated, was one of the key factors that made the experiment a success. The average output per man per shift for the 2 months of operation was nearly 56 tons, considerably larger than expected and over three times as large as the average for the Piokee unit in 1956. Despite the large outlay for bonuses, the total cost per ton for labor charged to mining, including bonuses, was less than half the average for the other Eagle-Picher mining units.

Other factors that contributed to the success of the project included: (1) Thorough planning of all phases of the operation before production began;

(2) selecting equipment best suited to the job; (3) the rigid preventive-maintenance and lubrication schedule for each diesel-powered unit; (4) preparing enough faces to allow routine cycling of drilling and loading; and (5) the fine cooperative spirit displayed by the workmen and supervisors.

In addition to the more tangible results, such as greatly increased unit output and lowered costs, the experimental project produced several long-range benefits, such as:

(1) Criteria that can be used to advantage, in future planning; in selecting a well-balanced series of job classifications; in selecting an equitable incentive bonus; in utilizing field testing equipment; and in setting up drilling, blasting, loading, hauling, and hoisting cycles.

(2) Allowing the geological and mining departments to accumulate more precise data on the tenor of ore for use in correcting or modifying estimates of ore reserves. Useful information also was acquired regarding ore trends, rock mechanics, mining methods, and drilling patterns.

(3) Results that created a favorable impression, psychologically, on the supervisors and workmen who participated directly or indirectly in the experiment. This impression inevitably will tend to raise efficiency standards throughout other operating units.

The Piokee project was brought to a close at the end of July 1957 when all operations in the district were suspended again. If the project had continued, the crew would have been reduced to nine men and the bonus base raised to 30 tons per man per shift. These changes, which the management was convinced would still further raise efficiency and lower costs, were suggested as a result of time-motion studies conducted on drilling, loading, and hauling cycles.

MINING COSTS

Mining costs per ton of ore produced at Piokee in 1956 and in the 2 months of experimental mining are summarized in tables 6 and 7, and 8 and 9, respectively.

TABLE 6. - Summary of underground costs, 1956

Tons of ore hoisted: 120,107 dry short tons.
Mining method: Open stopes with and without pillar support.

	Underground costs per ton of ore hoisted						
	Labor[1/]	Supervision	Compressed-air drills and steel	Power	Explosives	Other supplies	Total
Development[2/]..	$0.055	$0.012	$0.014	-	$0.012	$0.028	$0.121
Mining[3/].......	.539	.047	.126	$0.025	.123	.302	1.162
Transportation.	.320	.047	-	.052	-	.158	.577
General expense	.011	.012	-	.003	-	.116	.142
Total.......	.925	.118	.140	.080	.135	.604	2.002

[1/] Includes 4.35 percent of direct labor costs for Social Security and unemployment benefits.
[2/] Includes longhole and churn-drill exploration costs.
[3/] Includes loading costs.

TABLE 7. - Summary of costs in units of labor, power, and supplies, 1956

Tons of ore mined and hoisted: 120,107 short dry tons.
Mining method: Open stopes with and without pillar support.

Labor (man-hours per ton):			
Breaking (drilling, blasting, trimming)			0.192
Loading			.067
Haulage and hoisting			.137
Supervision			.040
General			.038
Total			.474
Average tons per man-shift			16.88
Labor, percent of total cost			52.10
Power and supplies:			
Explosives (40- and 47-percent strength)		lb./ton	0.672
Total power		kw.-hr./ton	7.68
Air compression	4.39		
Hoisting	1.60		
Loading	.99		
Pumping	.10		
Ventilation	.20		
Lighting	.26		
Development	.14		
Other supplies, percent of total power and supplies			62.98
Power and supplies, percent of total cost			47.90

TABLE 8. - Summary of underground costs, experimental project, June-July 1957

Tons of ore hoisted: 27,691 dry short tons.
Mining method: Open stopes with pillar support.

	Underground costs per ton of ore hoisted						
	Labor[1]	Supervision	Compressed-air drills and steel	Power	Explosives	Other supplies	Total
Development....	$0.006	-	-	-	-	$0.005	$0.011
Mining[2]	.229	$0.041	$0.114	-	$0.173	[3].225	.782
Transportation.	.159	.040	-	$0.051	-	.090	.340
General expense	.028	-	-	-	-	.091	.119
Total.......	.422	.081	.114	.051	.173	.411	1.252

[1] Includes 4.35 percent of direct labor costs for Social Security and unemployment benefits.
[2] Includes loading costs.
[3] Includes $0.22 per ton amortization on new rubber-tired loader.

TABLE 9. - Summary of costs in units of labor, power, and supplies, experimental project, June-July 1957

Tons of ore mined and hoisted: 27,691 dry short tons.
Mining method: Open stopes with pillar support.

Labor (man-hours per ton):		
Breaking (drilling, blasting, trimming)........		0.055
Loading........		.013
Haulage and hoisting........		.041
Supervision........		.021
General........		.014
Total........		.144
Average tons per man-shift........		55.55
Labor, percent of total cost........		40.18
Power and supplies:		
Explosives (47-percent strength)........lb./ton		0.981
Total power........kw.-hr./ton		4.40
Air compression........	2.25	
Hoisting........	1.55	
Pumping........	.06	
Ventilation........	.34	
Lighting........	.20	
Other supplies, percent of total power and supplies........		54.87
Power and supplies, percent of total cost........		59.82

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